Technical contribution

Length–weight relationships of 22 fish species from the East China Sea

M. Yagi*, M. Yamada, M. Shimoda, J. Uchida, T. Kinoshita, K. Shimizu, N. Yamawaki, T. Aoshima, Y. Morii and H. Kanehara

Faculty of Fisheries, Nagasaki University, 1-14 Bunkyo, 851-8512 Nagasaki, Japan

Summary

Estimated length–weight relationships are presented for 22 commercially important marine fish species, representing nine families, found in the East China Sea. A total of 2776 specimens were caught by otter trawling on the continental shelf in the East China Sea between 2009 and 2013. Information pertaining to length–weight relationships should lead to a better understanding of fish communities in the East China Sea.

***Corresponding author:** Mitsuharu Yagi, Faculty of Fisheries, Nagasaki University, 1-14 Bunkyo, Nagasaki, 852-8521, Japan

E-mail: yagi-m@nagasaki-u.ac.jp

Introduction

The body size of animals is related to most of their physiological and ecological traits via size-scaling effects (Calder, 1984; Schmidt-Nielsen, 1984; Sibly et al., 2012). Body weight is the best measure of body size used in both physiological and ecological studies, because many attributes vary with body weight (Peters, 1983; Hildrew at al., 2007; Glazier, 2005). Whereas body weight can used for meaningful comparisons, length cannot be directly compared between groups of animals differing in shape. Thus, comparison between groups of animals on the basis of length may be misleading (Hedges, 1985; Meiri, 2010), although length measurements are considerably easier and faster in field conditions than direct body weight measurements (Froese, 1998; Harrison, 2001).

Estimating the length–weight relationships of fish species can not only be useful for indirect estimation of body weight on the basis of body length but it can also provide information pertaining to body condition and growth patterns (Anderson and Neumann, 1996). The relationships between length and body weight is expressed using the allometric formula: $M = aL^b$, where M is body weight, L is length, a is a regression coefficient and b is a regression exponent. The regression coefficient for isometric growth is ‘3’, with values greater or less than ‘3’ indicating allometric growth (Tesch, 1971).

In this study, we present the length–weight relationships of 22 fish species from the East China Sea, which were collected between 2009 and 2013. These species were representative of most of those targeted by local fisheries. The East China Sea includes temperate and sub-tropical zones bordered by China, Korea and Japan, and it covers a large continental shelf. The hydrography is characterized mainly by the Kuroshio, which flows north-eastward along the eastern margin of the continental shelf, the two branches of the Kuroshio, the northward flowing Tsushima and Taiwan warm currents, and the southward flowing cold currents along the coast of China (Ichikawa and Beardsley, 2002).

Materials and Methods

Specimens were caught between April 2009 and September 2013. Fish were caught by otter trawling in the East China Sea. Trawling was conducted by the training ship Nagasaki Maru, Nagasaki University, Japan, which is an 842-tonne stern trawler. A bottom trawl net, which had a 5 cm main trawl and 3 cm codend mesh, was towed for 60–90 min at approximately 3 knots. The net mouth was approximately 17 m in width and 10 m in height (Yagi et al., 2013).

The total body length was measured to the nearest lower millimetre using a ruler. Body weight was weighed using a digital balance to an accuracy of 1 g. These body measurements were then used to estimate the length–weight relationships. They were calculated by ordinary least-squares regression using the log-transformed allometric equation: $\log M = \log a + b \log L$, where M represents wet body weight (g) and L represents total length (cm). Outliers owing to damage from the trawl were eliminated from the data in the analysis. The degree and direction of the linear association between the variables, i.e. body length and weight, were measured based on the coefficient of determination R^2. The scientific name used was according to Froese and Pauly (2013).

Results

In total, 2776 specimens were analysed. Table 1 shows the length–weight relationships obtained for the 22 fish species, which represented nine families. New maximum total lengths based on Froese and Pauly (2013) were established for *Upeneus japonicus* (Table 1 in bold). The statistical length–weight relationships were highly significant ($p < 0.001$) for all species. R^2 ranged between 0.952 for *Zeus faber* and 0.980 for *Doederleinia berycoides*. The high values of R^2 indicate a high degree of positive correlation between total length and body weight of all species.

The regression coefficient *a* ranged from 0.00237 (95% confidence interval (CI): 0.000775–0.00727) for *Sphyraena japonica* to 0.0436 for *Lepidotrigla microptera* (CI: 0.0352–0.0540), whereas the regression exponent *b* ranged from 2.61 (CI: 2.47–2.74) for *Upeneus japonicus* to 3.36 for *Callanthias japonicus* (CI: 3.14–3.59).

Discussion

To the best of our knowledge, this is the first report of the length–weight relationships for 19 fish species from the East China Sea, whereas the relationships for the remaining three species (*Pagrus* *major, Pleuronichthys cornutus* and *Tanakius kitaharae*) have been were previously reported (Froese and Pauly, 2013). Froese (2006) reported that 90% of the regression coefficient a ranged from 0.001 to 0.05, and that of the regression exponent b ranged from 2.7 to 3.4 based on 3929 records for 1773 species. In this study, both parameters of *a* and *b* with high R^2 (<0.95) for all species in the East China Sea were within the expected range; thus, the relationships between them appear to be reasonable.

It is recognized that length–weight relationships are not constant in fishes throughout the year; they may vary according to several factors including growth phase, food availability, feeding rate, gonad development and spawning frequency (Safran, 1992; Froese, 2006; Genkai-Kato and Miyasaka, 2007). In this study, because the fishes were in the adult stage and were collected over an extended period of time, these data should avoid the requirement of fishes in juvenile or immature stages, which would limit the size range when estimating the log-log linear regression parameters. Our data are also not representative of any particular season or time of the year; thus, they can be treated as mean annual values for comparative purposes. These results should be helpful for fisheries management, and they should constitute a benchmark for future research in the East China Sea.

Acknowledgements

We acknowledge the crew of the training ship Nagasaki Maru, Nagasaki University, Japan for their help in operating the vessel. This study was supported partly by the Ministry of Education, Culture, Sports, Science and Technology of Japan.

References

Anderson, R. O.; Neumann, R. M., 1996: Length, weight, and associated structural indices. In: Fisheries Techniques, 2nd edn. Eds: L. A. Nielson; D. L. Johnson. American Fisheries Society, Bethesda, pp. 447-482.

Calder, W. A. III., 1984: Size, function, and life history. Harvard University Press, Cambridge, pp. 448.

Froese, R., 1998: Length-weight relationships for 18 less-studied fish species. J. Appl. Ichthyol. 14, 117-118.

Froese, R., 2006: Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol. 22, 241-253.

Froese, R.; Pauly, D., (Eds). 2013: FishBase. World Wide Web electronic publication. Available at: http://www.fishbase.org (accessed on 18 January 2014).

Genkai-Kato, M.; Miyasaka, H., 2007: Length-weight relationships of four predatory stonefly species in Japan. Limnology 8, 171-174.

Glazier, D. S., 2005: Beyond the ‘3/4-power law’: variation in the intra- and interspecific scaling of metabolic rate in animals. Biol. Rev. Camb. Philos. Soc. 80, 611-662.

Harrison, T. D., 2001: Length-weight relationships of fishes from South African estuaries. J. Appl. Ichthyol. 17, 46-48.

Hedges, S. B., 1985: The influence of size and phylogeny on life history variation in reptiles: a response to Stearns. Am. Nat. 126, 258-260.

Hildrew, A. G.; Raffaelli, D. G.; Edmonds-Brown, R., (Eds), 2007: Body size: the structure and function of aquatic ecosystems. Cambridge University Press, Cambridge, pp. 343.

Ichikawa, H.; Beardsley, R. C., 2002: The current system in the Yellow and East China Seas. J. Oceanogr. 58, 77-92.

Meiri, S., 2010: Length-weight allometries in lizards. J. Zool. 281, 218-226.

Peters, R. H., 1983: The ecological implications of body size. Cambridge University Press, Cambridge, pp. 344.

Safran, P., 1992: Theoretical analysis of the weight-length relationship in fish juveniles. Mar. Biol. 112, 545-551.

Schmidt-Nielsen, K., 1984: Scaling. Why is animal size so important? Cambridge University Press, Cambridge, pp. 256.

Sibly, R. M.; Brown, J. H.; Kodric-Brown, A., 2012: Metabolic ecology: a scaling approach. John Wiley & Sons, Oxford, pp. 392.

Tesch, F. W., 1971: Age and growth. In: Methods for assessment of fish production in fresh waters. Ed: W. E. Ricker. Blackwell Scientific Publications, Oxford, pp. 99-130.

Yagi, M.; Shimoda, M.; Uchida, J.; Shimizu, K.; Aoshima, T.; Kanehara, H., 2013: Record body size of the beach conger *Conger japonicus* (Anguilliformes: Congridae) in the East China Sea. Mar. Biodivers. Rec. 6, e110.

Table 1 Length–weight relationships for 27 fish species collected from the East China Sea. Species name in bold type signifies new maximum total length

Family	Species	N	*L*		*W*		*a*		*b*		R^2
			Min	Max	Min	Max	Value	95% CI (upper-lower)	Value	95% CI (upper-lower)	
Aulopiformes	*Saurida undosquamis*	38	14.5	48.8	23	890	0.0112	0.00628 - 0.0200	2.85	2.67 - 3.02	0.968
Lophiiformes	*Lophius litulon*	19	11	32	34	770	0.0225	0.00848 - 0.0595	2.94	2.63 - 3.26	0.958
Ophidiiformes	*Hoplobrotula armata*	67	24	62.4	93	1800	0.00488	0.00302 - 0.00789	3.10	2.96 - 3.24	0.968
Perciformes	*Callanthias japonicus*	33	21	28	122	318	0.00415	0.00200 - 0.00861	3.36	3.14 - 3.59	0.967
Perciformes	*Carangoides equula*	353	8.3	35	10	760	0.0166	0.0144 - 0.0191	3.00	2.95 - 3.05	0.977
Perciformes	*Pagrus major*	82	11.1	91	19	9000	0.0191	0.0123 - 0.0296	2.92	2.81 - 3.04	0.971
Perciformes	*Cookeolus japonicus*	33	15	47	81	1700	0.0469	0.0302 - 0.0731	2.70	2.56 - 2.85	0.979
Perciformes	*Doederleinia berycoides*	40	15.2	32.8	48	480	0.0183	0.0120 - 0.0281	2.92	2.78 - 3.05	0.980
Perciformes	*Dentex tumifrons*	547	11.1	32.3	32	651	0.0471	0.0417 - 0.0532	2.72	2.68 - 2.76	0.972
Perciformes	*Sphyraena japonica*	20	27.8	36.1	112	260	0.00237	0.000775 - 0.00727	3.22	2.90 - 3.55	0.960
Perciformes	*Trachurus japonicus*	249	10.4	28	11	200	0.00950	0.00785 - 0.0115	2.98	2.91 - 3.04	0.970
Perciformes	***Upeneus japonicus***	49	13	28	24	202	0.0326	0.0.0220 - 0.0481	2.61	2.47 - 2.74	0.970
Pleuronectiformes	*Pleuronichthys cornutus*	39	9.2	28	11	207	0.0245	0.0148 - 0.0407	2.75	2.59 - 2.92	0.968
Pleuronectiformes	*Tanakius kitaharae*	17	12.8	26.4	24	182	0.0267	0.0141 - 0.0509	2.67	2.44 - 2.90	0.976
Scorpaeniformes	*Chelidonichthys spinosus*	30	12	32	12	416	0.00528	0.00278 - 0.0100	3.21	2.98 - 3.45	0.966
Scorpaeniformes	*Lepidotrigla microptera*	140	12	28	23	202	0.0326	0.0263 - 0.0404	2.63	2.54 - 2.70	0.972
Scorpaeniformes	*Sebastiscus tertius*	206	11.4	52	30	2000	0.0356	0.0285 - 0.0445	2.79	2.72 - 2.86	0.970

Syngnathiformes	*Macroramphosus scolopax*	14	13.6	18	14	33	0.00964	0.000367 - 0.0253	2.80	2.45 - 3.14	0.962
Tetraodontiformes	*Aluterus monoceros*	55	12	30	28	433	0.0222	0.0142 - 0.0347	2.86	2.71 - 3.01	0.964
Tetraodontiformes	*Lagocephalus wheeleri*	95	14.5	23.2	37	164	0.0131	0.00919 - 0.0186	2.98	2.86 - 3.10	0.964
Tetraodontiformes	*Thamnaconus modestus*	66	15.2	32	50	400	0.0250	0.0154 - 0.0405	2.80	2.65 - 2.95	0.956
Zeiformes	*Zeus faber*	584	10	43	14	1365	0.0264	0.0227 - 0.0307	2.82	2.76 - 2.87	0.952

N, sample size; Min, minimum; Max, maximum; *L*, total length in cm; *W*, wet body weight in g; *a* and *b* are the parameters of the length–weight relationship; CI, confidence interval; R^2, coefficient of determination